Chapter 17

PRACTICE EXERCISES

Section I Multiple Choice

1. A two slit interference experiment is performed with slit spacing a and wavelength λ. As the spacing is increased, holding λ fixed, which of the following is true?
   I. The width of the central maximum will decrease.
   II. The width of the central maximum will increase.
   III. There will be more interference fringes formed.

   (A) I only (B) II only (C) III only (D) I and III (E) II and III

2. A Young's apparatus consisting of two identical narrow slits is illuminated with light of wavelength λ. If the spacing between the slits is 3.7λ, the maximum number of interference maxima observed will be

   (A) 0 (B) 1 (C) 3 (D) 6 (E) 7

3. A single slit with width w produces a diffraction pattern on a screen when illuminated with light of a given wavelength. The entire experiment is then immersed in water with the same light source. Which of the following is true?

   (A) The diffraction pattern will contract.
   (B) The diffraction pattern will expand.
   (C) The diffraction pattern will be unchanged.
   (D) The diffraction pattern will disappear.
   (E) The central maximum becomes less intense than the secondary maxima.

4. Two parallel glass plates are separated by an air space 300 nm thick. When illuminated with various monochromatic light sources from directly above the plates, which wavelength will produce the least amount of reflected light?

(A) 400 nm (B) 450 nm (C) 500 nm (D) 550 nm (E) 600 nm

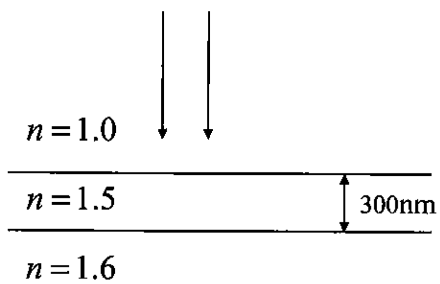

Figure 13

5. Light of several wavelengths is incident from above on a thin film of index 1.5 and thickness 300 nm that's coated on a surface with index 1.6. Which wavelength will produce the most reflected light?

(A) 400 nm (B) 450 nm (C) 500 nm (D) 550 nm (E) 650 nm

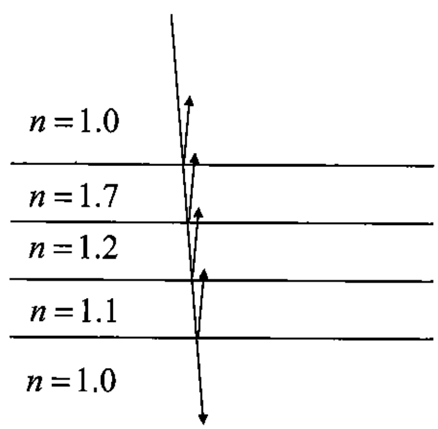

Figure 14

6. Three layers of transparent material with different indices of refraction are laminated to form a single device. When illuminated from above, reflections will occur at the various interfaces. The number of reflected rays experiencing a phase shift is

(A) 0 (B) 1 (C) 2 (D) 3 (E) 4

CHAPTER 17

PRACTICE EXERCISES

SECTION II FREE REPONSE

1. Light consisting of two wavelengths, 500 nm and 600 nm, is incident upon a screen that has two narrow slits separated by a distance a. A second screen is placed 1 m behind the first screen. It's observed that the shorter wavelength has its first order maximum form on the second screen 0.015 m above the center of the central maximum.
   (a) Determine the spacing between the two slits.
   (b) Determine the distance from the central maximum to the first order maximum of the longer wavelength.
   (c) One of the slits is covered up. Describe any changes in the pattern appearing on the second screen.

2. A thin film with index of refraction 1.4 is to be coated onto a glass surface, index of 1.5, to remove red light of wavelength 600 nm from the reflections.
   (a) What is the minimum film thickness that will do the job?
   (b) At this thickness, will there be any visible wavelengths that will be enhanced in the reflected light?

Answers and Explanations

MULTIPLE CHOICE

1. The answer is D. Rearranging the maxima formula, you have $\sin\theta = \frac{N\lambda}{a}$. Making a larger will make θ smaller, so the width of all its dimensions decreases. The largest order maximum can be determined by looking at a 90° angle.

   $a \sin 90 = N\lambda \quad \Rightarrow N = \frac{a}{\lambda}$ Thus as a gets larger, N also gets larger.

2. The answer is E. From the previous explanation, you have at 90°

   $$N = \frac{a}{\lambda} = 3.7$$

   This means that the fourth order maximum doesn't form. There are 3 maxima for each order, one on each side of the central maximum, and when they're added to the central maximum itself you have a total of 7.

3. The answer is A. Rewriting the diffraction minima formula, you have

$$\sin\theta = \frac{N\lambda}{w}$$

As w gets bigger, θ will get smaller, indicating a contracting pattern.

4. The answer is E. There will be a phase shift at only one interface, where the ray moves from air to glass. For a minimum to occur, you need the physical path difference, $2d = 600$ nm, to be a multiple of the wavelength. E obviously satisfies this for $N = 1$.

5. The answer is B. There will be two phase shifts that compensate for each other when the rays are brought back together. For constructive interference, you need the two rays to have the 600 nm path difference in the film be an integral multiple of the wavelength in the film. The wavelength in the film is $\lambda' = \frac{\lambda}{1.5}$. For B, this gives you 300 nm, and the path difference is two wavelengths.

6. The answer is B. Only at the first interface do you have a ray going from a lower index medium to a higher index medium.

FREE RESPONSE

1. (a) You can use geometry to find the angle for the first maximum, then use the maxima formula to find the spacing.

$$\tan\theta = \frac{0.015}{1} \Rightarrow \theta = 0.859°$$

$$a\sin(0.859) = 500 \times 10^{-9} \Rightarrow a = 3.33 \times 10^{-5}\text{ m}$$

It's worth noting that the small angle approximation can often be used in these problems. In this approximation, $\sin\theta \cong \tan\theta$, and you can use the tangent in the maxima formula directly and avoid actually solving for the angle.

(b) Using your result and the small angle approximation, you have

$$a\sin\theta \cong a\tan\theta = 600 \times 10^{-9}$$

$$3.33 \times 10^{-5}\frac{x}{1} = 600 \times 10^{-9} \Rightarrow x = 0.018$$

(c) With one slit covered, you have a single slit diffraction pattern for each wavelength. Each color will have a broad central maximum, with the first order minimum occurring at different positions. The other maxima will also occur at different positions, but they'll be much less intense than the central maximum.

2. (a) There will be a phase shift at each reflection, since each interface involves moving to a medium with a higher index of refraction. The effects of the phase changes then cancel out in determining maxima and minima. To get a minimum in the 600 nm light, you need the path difference to be $\frac{1}{2}$ the wavelength in the film. Then you have

$$2d = \frac{1}{2}\frac{600}{1.4} \Rightarrow d = 107 \text{ nm}$$

(b) For maxima to occur, you need the path difference in the film to be an integral multiple of the wavelength in the film, so

$$2(107) = N\frac{\lambda}{1.4} \quad N = 1, 2 \ldots$$

For $N = 1$, this gives you 300 nm, out of the visible range. All other enhanced wavelengths will also be in the ultraviolet, so the answer is no, there are no visible wavelengths enhanced in the reflected light.